

Supporting Information

COVID-19 Vaccine Frontrunners and Their Nanotechnology Design

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Table S1: List of Vaccines Undergoing Development Against SARS-CoV-2

Company/Laboratory	Vaccine Platform	Status	Reference
Live-Attenuated Vaccines			
<ul style="list-style-type: none"> Codagenix Incorporation The Serum Institute of India 	<ul style="list-style-type: none"> Live-attenuated vaccine using proprietary viral deoptimization techniques 	<ul style="list-style-type: none"> Mapped out several possible candidates on February 2020 	1
<ul style="list-style-type: none"> German Center for Infection Research (DZIF) 	<ul style="list-style-type: none"> Using an attenuated viral vaccine of the measles virus targeting the S and nucleocapsid protein 		2,3
<ul style="list-style-type: none"> Indian Immunological Limited Griffith University 	<ul style="list-style-type: none"> Utilizing codon de-optimization technology for a prophylactic, active, single-dose vaccination 		4
<ul style="list-style-type: none"> Mehmet Ali Aydinlar University Acibadem Labmed Health Services A.S. 	<ul style="list-style-type: none"> Using a codon deoptimized live attenuated virus 		5,3
<ul style="list-style-type: none"> Meissa Vaccines 	<ul style="list-style-type: none"> Vaccine name MV-014-210 using the same platform as vaccine candidates for RSV 	<ul style="list-style-type: none"> Hopes to start Phase I beginning of 2021 	6
Inactivated Vaccines			
<ul style="list-style-type: none"> Sinovac Instituto Butantan Bio Farma 	<ul style="list-style-type: none"> Formalin inactivated whole virus particles Called CoronaVac 	<ul style="list-style-type: none"> Currently in Phase III clinical trials 	3,7
<ul style="list-style-type: none"> Sinovac Dynavax 	<ul style="list-style-type: none"> Sinovac's formalin-inactivated whole virus particles along with Dynavax's CpG 1018 		8

	adjuvant		
<ul style="list-style-type: none"> Valneva Dynavax 	<ul style="list-style-type: none"> Valneva is utilizing its IXIARO platform (previously used for Japanese encephalitis) based on Vero-cell, inactivated, whole virus vaccines Dynavax is providing its CpG 1018 adjuvant Named VLA2001 		9
<ul style="list-style-type: none"> Research Institute for Biological Safety Problems Republic of Kazakhstan 	<ul style="list-style-type: none"> Inactivated vaccine developed from viral strains isolated from Kazakhstan patients 		10,35
<ul style="list-style-type: none"> Beijing Minhai Biotechnology Co. Ltd 	<ul style="list-style-type: none"> Inactivated whole virus 		35
<ul style="list-style-type: none"> Osaka University Research Foundation for Microbial Diseases of Osaka University National Institutes of Biomedical Innovation, Health, and Nutrition 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,5
<ul style="list-style-type: none"> Beijing Institute of Biological Products Sinopharm 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Currently in Phase III clinical trials Vaccine could be ready for use by end of 2020 	11,12
<ul style="list-style-type: none"> Wuhan Institute of Biological Products Sinopharm 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Currently in Phase III clinical trials Vaccine could be ready for use by end of 2020 Already received emergency authorization use for employees of state-owned businesses 	12,13

		that require travel	
<ul style="list-style-type: none"> Institute of Medical Biology, Chinese Academy of Medical Sciences 	<ul style="list-style-type: none"> No public information other than a listing on in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	3,14
<ul style="list-style-type: none"> Bharat Biotech 	<ul style="list-style-type: none"> Called Covaxin Inactivated SARS-CoV-2 vaccine 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	15,16
<ul style="list-style-type: none"> KM Biologics 	<ul style="list-style-type: none"> Inactivated vaccine plus alum using the same platform as vaccine candidates for Japanese Encephalitis and Zika 		3,5
<ul style="list-style-type: none"> Erciyes University 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,17
<ul style="list-style-type: none"> National Research Centre, Egypt 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,18
<ul style="list-style-type: none"> OSAKA University BIKEN NIBIOHN 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> Selcuk University 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,19
Subunit Vaccines			
<ul style="list-style-type: none"> Clover Biopharmaceuticals Incorporation GlaxoSmithKline (GSK) 	<ul style="list-style-type: none"> COVID-19 S-trimer vaccine, which resembles the native trimeric S protein of SARS-CoV-2 created using Clover's Trimer-Tag technology Pandemic adjuvant system by GSK to be utilized alongside the vaccine 	<ul style="list-style-type: none"> Currently in Phase I clinical trials 	20,21
<ul style="list-style-type: none"> U.S. Army Institute of Infectious Diseases 	<ul style="list-style-type: none"> Ferritin nanoparticle vaccine derived from <i>H. pylori</i> delivering the RBD of the S 		22

<ul style="list-style-type: none"> Walter Reed Army Institute of Research 	<ul style="list-style-type: none"> protein Proprietary lipid ring around the ferritin nanoparticle acts as an adjuvant 		
<ul style="list-style-type: none"> Clover Biopharmaceuticals Incorporation Dynavax 	<ul style="list-style-type: none"> COVID-19 S-trimer vaccine, which resembles the native trimeric S protein of SARS-CoV-2 created using Clover's Trimer-Tag technology CpG 1018 by Dynavax as adjuvant 	<ul style="list-style-type: none"> Currently in Phase I clinical trials 	21,23
<ul style="list-style-type: none"> National Institute of Infectious Disease, Japan 	<ul style="list-style-type: none"> S protein subunit vaccine along with adjuvant 		3,5
<ul style="list-style-type: none"> University of Queensland CSL Seqirus 	<ul style="list-style-type: none"> Molecular clamp stabilizes the S protein allowing the immune system to better recognize and neutralize the antigen Injected with CSL adjuvant 	<ul style="list-style-type: none"> Currently in Phase I clinical trials 	24,25
<ul style="list-style-type: none"> Medigen Biotechnology Institute National Institute of Health Dynavax 	<ul style="list-style-type: none"> Stable, prefusion form of S protein of SARS-CoV-2 subunit vaccine with Dynavax's CpG 1018 adjuvant Called MVC-COV1901 	<ul style="list-style-type: none"> Not yet recruiting for Phase I clinical testing, which is starting in September 	26–28
<ul style="list-style-type: none"> Innovax Biotech Xiamen University GSK 	<ul style="list-style-type: none"> S protein epitope vaccine candidate named XWG-03 Injected with GSK pandemic adjuvant system AS03 	<ul style="list-style-type: none"> GSK expects preclinical data to be released within the three months of April 	29,30
<ul style="list-style-type: none"> Intravacc EpiVax 	<ul style="list-style-type: none"> Approach 1: Outer membrane vesicle (OMV) peptide vaccine Approach 2: OMV subunit vaccine 	<ul style="list-style-type: none"> Phase I studies to begin in Q4 of 2020 	3,31
<ul style="list-style-type: none"> Novavax Emergent BioSolutions 	<ul style="list-style-type: none"> Vaccine name: NVX-CoV2373 Stable, pre-fusion, full-length S protein made from Novavax's proprietary VLP nanoparticle technology given with Novavax's proprietary saponin-based adjuvant, Matrix-M™ 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials Released positive Phase I data through press release 	32–34

	<ul style="list-style-type: none"> Antigens created through Sf9/baculovirus insect cell platform 		
<ul style="list-style-type: none"> iBio CC-Pharming Limited 	<ul style="list-style-type: none"> Creation of SARS-CoV-2 subunit VLP-based constructs using plant-based <i>FastPharming</i> System™ Called IBIO-200 Researching both glycosylated and non-glycosylated constructs 	<ul style="list-style-type: none"> Began immunization studies in March, 2020 	35–37
<ul style="list-style-type: none"> Saint-Petersburg Scientific Research Institute of Vaccines and Serums 	<ul style="list-style-type: none"> Recombinant protein nanoparticle vaccine based upon the S protein as well as other epitopes 	<ul style="list-style-type: none"> Completed animal studies and has shown promising results 	3,38
<ul style="list-style-type: none"> University of Saskatchewan VIDO-InterVac 	<ul style="list-style-type: none"> Microsphere subunit vaccine against the S protein of SARS-CoV-2 with adjuvant 	<ul style="list-style-type: none"> Completed studies in ferrets and has found manufacturers for human clinical trials Hoping for approval by 2021 	39,40
<ul style="list-style-type: none"> OncoGen 	<ul style="list-style-type: none"> Vaccinomics-identified peptides are customized to fit immune profiles of target populations Multiepitope long peptide candidates against the S and membrane protein of SARS-CoV-2 capable of producing CD4+ and CD8+ T-cell responses 	<ul style="list-style-type: none"> <i>In vitro</i> testing on human cell lines 	41
<ul style="list-style-type: none"> Vaxine Medytox 	<ul style="list-style-type: none"> Used computer modeling and cloud computing techniques to develop vaccine of the S protein that blocks the S from binding to the ACE-2 receptor Administered with Advax™ adjuvant Called Covax-19 	<ul style="list-style-type: none"> Completed Phase I clinical trials Hopes to start Phase II clinical trials in September 	42–44
<ul style="list-style-type: none"> MIGAL Galilee Research Institute 	<ul style="list-style-type: none"> Oral delivery of S and neurocapsid antigen vaccine based off of its past avian 	<ul style="list-style-type: none"> In February, said vaccine should be ready for 	45

	infectious bronchitis virus developed with E. coli protein expression system	animal testing in 90 days	
<ul style="list-style-type: none"> • HaloVax • The Vaccine & Immunotherapy Center at the Massachusetts General Hospital 	<ul style="list-style-type: none"> • Self-assembling vaccine composed of a heat shock protein and Avidin decorated with neoantigens of SARS-CoV-2 	<ul style="list-style-type: none"> • Animal study completion date (October, 2020) 	46
<ul style="list-style-type: none"> • Immune System Regulation Holding • TCER AB 	<ul style="list-style-type: none"> • Based on ISR50 immunostimulation with SARS-CoV-2 proteins created by TCER AB 	<ul style="list-style-type: none"> • Hopes to begin Phase I clinical testing (Q4, 2020) 	5,47
<ul style="list-style-type: none"> • University of California, San Diego 	<ul style="list-style-type: none"> • Microneedle patch delivery of legume-infecting plant viruses engineered to present SARS-CoV-2 peptides on the viral capsid 		48
<ul style="list-style-type: none"> • University of Alberta 	<ul style="list-style-type: none"> • Spike protein subunit vaccine against SARS-CoV-2 	<ul style="list-style-type: none"> • Hopes to begin Phase I testing by the end of 2020 	49,50
<ul style="list-style-type: none"> • LakePharma Incorporation 	<ul style="list-style-type: none"> • No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> • Quadram Institute Biosciences • University of Kent 	<ul style="list-style-type: none"> • Mucosal vaccine of OMVs created by resident gut bacteria carrying SARS-CoV-2 subunits • OMV acts as its own adjuvant 		51,52
<ul style="list-style-type: none"> • BiOMViS Srl • University of Trento 	<ul style="list-style-type: none"> • OMV-based vaccine decorated with the S protein of SARS-CoV-2 	<ul style="list-style-type: none"> • Animal studies in mice showed neutralization capabilities 	3,53
<ul style="list-style-type: none"> • AnyGo Technology 	<ul style="list-style-type: none"> • Recombinant S1-Fc fusion subunit vaccine expressed in CHO-K1 cells and given with Advaccine Bipharmas AD11.10 saponin-based adjuvant 	<ul style="list-style-type: none"> • Completed animal testing in mice, rabbits, and monkeys 	54

<ul style="list-style-type: none"> Yisheng Biopharma 	<ul style="list-style-type: none"> No public information other than a listing on in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Currently in animal testing 	55
<ul style="list-style-type: none"> VABIOTECH Bristol University 	<ul style="list-style-type: none"> Insect cell – baculovirus expression vector system (BEVS) for S protein 	<ul style="list-style-type: none"> Started animal studies Hopes to have vaccine within 12-18 months of May, 2020 	3,56
<ul style="list-style-type: none"> Applied Biotechnology Institute Incorporation 	<ul style="list-style-type: none"> Heat stable subunit vaccine delivered orally 		3
<ul style="list-style-type: none"> Axon Neuroscience SE 	<ul style="list-style-type: none"> Peptide vaccine against S protein capable of producing T and B-cell immune responses and blocking S protein interactions with target cells 	<ul style="list-style-type: none"> Plans to begin clinical trials in Autumn of 2020 Plans to launch vaccine in 2021 	57,58
<ul style="list-style-type: none"> Anhui Zhifei Longcom Biopharmaceutical Institute of Microbiology, Chinese Academy of Sciences 	<ul style="list-style-type: none"> RBD-dimer recombinant subunit vaccines Given along with adjuvant 	<ul style="list-style-type: none"> Currently in Phase II of clinical testing 	3,59
<ul style="list-style-type: none"> Neovii Tel Aviv University 	<ul style="list-style-type: none"> RBD subunit vaccine 	<ul style="list-style-type: none"> “Ready to use within a year to a year and a half” (from May 13, 2020) 	60
<ul style="list-style-type: none"> Verndari Incorporation University of California, Davis 	<ul style="list-style-type: none"> Delivery of SARS-CoV-2 S protein antigens using Vendari’s patented VaxiPatch dermal, microneedle array platform Patch contains temporary dye for proof of vaccination 	<ul style="list-style-type: none"> Animal testing began on May 1, 2020 	61–63

<ul style="list-style-type: none"> Kentucky Bioprocessing, Incorporation 	<ul style="list-style-type: none"> Called KBP-COVID-19 Injection of tobacco plants with modified coronavirus to produce SARS-CoV-2 RBD antigens 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	64,65
<ul style="list-style-type: none"> ImmunoPrecise LiteVax BV 	<ul style="list-style-type: none"> S protein subunit vaccine developed from the PolyTope monoclonal antibody by ImmunoPrecise Given with LiteVax's adjuvant 	<ul style="list-style-type: none"> Preclinical testing to begin in August, 2020 	66
<ul style="list-style-type: none"> MOGAM Institute for Biomedical Research GC Pharma 	<ul style="list-style-type: none"> Subunit vaccine with adjuvant 		67
<ul style="list-style-type: none"> Lomonosov Moscow State University 	<ul style="list-style-type: none"> Denatured tobacco mosaic virus particles reformulated into spherical particles for a subunit vaccine 		3,68
<ul style="list-style-type: none"> Baiya Phytopharm Chula Vaccine Research Center 	<ul style="list-style-type: none"> Subunit vaccine (RBD-Fc) developed in plants given alongside adjuvant 		3
<ul style="list-style-type: none"> Innomedica 	<ul style="list-style-type: none"> Developed with in-house patented liposome delivery system for delivery of SARS-CoV-2 surface proteins 		69
<ul style="list-style-type: none"> PDS Biotechnology 	<ul style="list-style-type: none"> Testing two different candidates: PDS0203, PDS0204 Utilizes the Versamune® platform that produces antibodies, T-cells, and memory T-cell responses 		70
<ul style="list-style-type: none"> University of Pittsburgh 	<ul style="list-style-type: none"> Finely-sized, microneedle patch vaccine named PittCoVacc that can hold up to 400 microneedles The microneedles hold a subunit of the S protein within a sugar-like substance 	<ul style="list-style-type: none"> Animal studies completed Phase I clinical trials (June, 2020) 	71,5

<ul style="list-style-type: none"> • Vaxil Bio Therapeutics 	<ul style="list-style-type: none"> • Vaccine developed from <i>in silico</i> screening via its VaxHit™ bioinformatics platform 	<ul style="list-style-type: none"> • Testing non-GMP manufactured vaccines pre-clinically 	72
<ul style="list-style-type: none"> • Osaka University • Research Foundation for Microbial Diseases of Osaka University • National Institutes of Biomedical Innovation, Japan 	<ul style="list-style-type: none"> • Virus like particle (VLP)-directed subunit vaccine along with adjuvant 		3
<ul style="list-style-type: none"> • Biological E Limited 	<ul style="list-style-type: none"> • Protein subunit vaccine of the RBD along with an adjuvant 		3
<ul style="list-style-type: none"> • Flow Pharma Incorporation 	<ul style="list-style-type: none"> • Room temperature stable, biodegradable, microsphere peptide vaccine called FlowVax Covid-19, which can be delivered both by inhalation and injection • Used along with an adjuvant 	<ul style="list-style-type: none"> • Entered into primate testing (April, 2020) 	73
<ul style="list-style-type: none"> • AJ Vaccines 	<ul style="list-style-type: none"> • Subunit vaccine of the S protein 	<ul style="list-style-type: none"> • Hopes to roll out vaccines by 2021 	74
<ul style="list-style-type: none"> • Generex Biotechnology Corporation • EpiVax 	<ul style="list-style-type: none"> • Vaccine based off of the NuGenerex Immuno-Oncology li-Key technology 	<ul style="list-style-type: none"> • Will test on recovered patient blood samples • In February, Generex planned to begin human testing in 90 days 	75,76
<ul style="list-style-type: none"> • EpiVax • University of Georgia 	<ul style="list-style-type: none"> • SARS-CoV-2 S subunit vaccine 		77
<ul style="list-style-type: none"> • Sanofi Pasteur • In collaboration with BARDA 	<ul style="list-style-type: none"> • S subunit vaccine created using the company's egg-free, recombinant DNA platform • DNA of the <i>baculovirus</i> expression 	<ul style="list-style-type: none"> • To begin testing <i>in vitro</i> within 4 months • To begin clinical testing in 12 to 18 months 	78

	platform is combined with the DNA encoding the S protein to produce the antigen		
<ul style="list-style-type: none"> • Sanofi Pasteur • GSK 	<ul style="list-style-type: none"> • Sanofi will utilize the same platform as with its BARDA collaboration while GSK will provide the adjuvant 	<ul style="list-style-type: none"> • Phase I clinical trial (September, 2020) 	79
<ul style="list-style-type: none"> • Heat Biologics • University of Miami • Waisman Biomanufacturing 	<ul style="list-style-type: none"> • The vaccine will utilize Heat Biologic's proprietary gp96 platform, which will incorporate SARS-CoV-2 antigens 		80
<ul style="list-style-type: none"> • Baylor College of Medicine • Allovir 	<ul style="list-style-type: none"> • Develop allogeneic, virus-specific T-cell therapy against SARS-CoV-2 		5
<ul style="list-style-type: none"> • IMV Incorporation 	<ul style="list-style-type: none"> • Delivery of SARS-CoV-2 epitopes using DPX, a lipid-based nanoparticle with no aqueous component 	<ul style="list-style-type: none"> • Hope to begin clinical study in summer 2020 	81
<ul style="list-style-type: none"> • Mynvax 	<ul style="list-style-type: none"> • RBD-protein 	<ul style="list-style-type: none"> • Completed initial animal trials 	82
<ul style="list-style-type: none"> • Izmir Biomedicine and Genome Center 	<ul style="list-style-type: none"> • Using the recombinant S protein 	<ul style="list-style-type: none"> • Successfully completed animal testing 	83,3
<ul style="list-style-type: none"> • AdaptVac • ExpreS2ion 	<ul style="list-style-type: none"> • ExpreS2ion creates empty VLPs with its novel <i>Drosophila</i> S2 insect cell expression system to present subunits of SARS-CoV-2 in a capsid like particle 	<ul style="list-style-type: none"> • Hopes to begin Phase I/IIa trials by February, 2021 	84
<ul style="list-style-type: none"> • ExpreS2ion 	<ul style="list-style-type: none"> • Subunit vaccine created in <i>Drosophila</i>S2 insect cell expression system 		3,5
<ul style="list-style-type: none"> • State Research Center of Virology and Biotechnology VECTOR • Rospotrebnadzor • Koltsovo 	<ul style="list-style-type: none"> • Approach 1: peptide vaccine • Approach 2: subunit vaccine 	<ul style="list-style-type: none"> • Phase I clinical trials (June 29, 2020) 	3

<ul style="list-style-type: none"> Shionogi 	<ul style="list-style-type: none"> Prophylactic recombinant SARS-CoV-2 protein vaccine developed in BEVS 		85
<ul style="list-style-type: none"> UMN Pharma (Shionogi) 	<ul style="list-style-type: none"> Utilizing its baculovirus expression vector system to develop a recombinant vector against S protein of SARS-CoV-2 	<ul style="list-style-type: none"> Phase I clinical trials (end of 2020) Hopes to roll out vaccine by 2021 	86
<ul style="list-style-type: none"> Bogazici University 	<ul style="list-style-type: none"> Peptide vaccine formulated as protein microspheres administered alongside a novel adjuvant 	<ul style="list-style-type: none"> Hopes to begin Phase I clinical trials in January, 2021 	87
<ul style="list-style-type: none"> University of Virginia 	<ul style="list-style-type: none"> Utilizing an S subunit intranasal liposomal formulation with GLA/3M052 adjuvants 		53
<ul style="list-style-type: none"> Sorrento Therapeutics 	<ul style="list-style-type: none"> Recombinant subunit fusion vaccine between S1 and F_c domain of human immunoglobulin Called T-VIVA-19 		5
<ul style="list-style-type: none"> National Research Centre, Egypt 	<ul style="list-style-type: none"> Subunit vaccine targeting the S, nucleocapsid, membrane, and S1 proteins 		5
<ul style="list-style-type: none"> Research Institute for Biological Safety Problems Republic of Kazakhstan 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,5
<ul style="list-style-type: none"> Helix Biogen Consult 	<ul style="list-style-type: none"> S protein subunit vaccine given alongside adjuvant Expressed in E. Coli system 		3,5
<ul style="list-style-type: none"> University of San Martin and Conicet, Argentina 	<ul style="list-style-type: none"> Subunit vaccine against antigens from SARS-CoV-2 strains circulating in Argentina Hopes for an oral formulation 	<ul style="list-style-type: none"> About to complete the preclinical studies phase 	88
<ul style="list-style-type: none"> Max-Planck Institute of Colloids and Interfaces 	<ul style="list-style-type: none"> Targeted to Langerhans cells in the skin Based on the S-protein of SARS-CoV-2 		5

<ul style="list-style-type: none"> • Epivax 	<ul style="list-style-type: none"> • Protein subunit vaccine providing T-cell-mediated protection using subunits that are conserved in all SARS-CoV-2 strains • Called EPV-COV-19 		89
<ul style="list-style-type: none"> • Chulalongkorn University • GPO, Thailand 	<ul style="list-style-type: none"> • RBD of SARS-CoV-2 fused to the Fc of immunoglobulin given alongside an adjuvant 		3
<ul style="list-style-type: none"> • Esco Aster • Vivaldi Biosciences 	<ul style="list-style-type: none"> • Injection of SARS-CoV-2 antigens conjoined with backbone of “flu” virus • Called DeltaCov 	<ul style="list-style-type: none"> • Hopes to begin clinical trials in November, 2020 	90
<ul style="list-style-type: none"> • Halovax • The Vaccine & Immunotherapy Center at the Massachusetts General Hospital 	<ul style="list-style-type: none"> • Self-assembled vaccine formulated from the fusion of heat shock proteins, avidin, and biotinylated immunogenic peptides 		3,5
<ul style="list-style-type: none"> • Codiak BioSciences • Ragon Institute 	<ul style="list-style-type: none"> • Co-delivery of immunogenic B and T-cell antigens to the same antigen presenting cell using Codiak’s exoVacc platform for exosomal delivery 		91

VLP Vaccines

<ul style="list-style-type: none"> • Medicago 	<ul style="list-style-type: none"> • Producing SARS-CoV-2 VLP vaccines in <i>Nicotiana benthamiana</i> 	<ul style="list-style-type: none"> • Currently in Phase I clinical testing 	
<ul style="list-style-type: none"> • Medicago • GSK 	<ul style="list-style-type: none"> • VLP vaccines given with GSK AS03 adjuvant 		5
<ul style="list-style-type: none"> • Medicago • Dynavax 	<ul style="list-style-type: none"> • VLP vaccines given with CpG 1018 adjuvant 		5
<ul style="list-style-type: none"> • Imophoron Limited • University of Bristol’s Max Planck Centre 	<ul style="list-style-type: none"> • S protein presenting vaccine based off of Imophoron’s ADDomer© self-assembling, VLP platform 	<ul style="list-style-type: none"> • Preclinical testing to begin “within weeks” 	92–94

<ul style="list-style-type: none"> • VBI Vaccines • National Research Council of Canada 	<ul style="list-style-type: none"> • Enveloped VLP platform (eVLP) expressing spike epitopes of SARS-CoV, SARS-CoV-2, Middle East respiratory syndrome for pan-coronavirus vaccine 	<ul style="list-style-type: none"> • Phase I testing (Q4 of 2020) 	5
<ul style="list-style-type: none"> • Saiba GmbH 	<ul style="list-style-type: none"> • VLP expressing the RBD of SARS-CoV-2 	<ul style="list-style-type: none"> • Pre-clinical proof-of-concept accomplished 	3,95
<ul style="list-style-type: none"> • Doherty Institute 	<ul style="list-style-type: none"> • No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> • OSIVAX 	<ul style="list-style-type: none"> • Universal VLP vaccine targeting an internal protein of SARS-CoV-2 		96
<ul style="list-style-type: none"> • ARTES Biotechnology 	<ul style="list-style-type: none"> • Approach 1: based upon ARTES' METAVAX enveloped VLP nanostructure platform • Approach 2: based upon ARTES' SplitCore capsid VLP platform • Both VLP platforms will present SARS-CoV-2 S domains with possible concurrent display of N protein 		97
<ul style="list-style-type: none"> • University of Sao Paulo 	<ul style="list-style-type: none"> • VLP-based vaccine with both B and T-cell peptide epitopes 		98
<ul style="list-style-type: none"> • NavarraBiomed, Oncoimmunology Group 	<ul style="list-style-type: none"> • Lentivirus and baculovirus VLP vaccine 		3
<ul style="list-style-type: none"> • Mahidol University • The Government Pharmaceutical Organization • Siriraj Hospital 	<ul style="list-style-type: none"> • No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> • IrsiCaixa AIDS Research • IRTA-CReSA • Barcelona Supercomputing Centre • Grifols 	<ul style="list-style-type: none"> • HIV VLPs with the S protein generated from the Barcelona Supercomputing Centre's structural models 		99,100

<ul style="list-style-type: none"> Middle East Technical University 	<ul style="list-style-type: none"> VLPs with the four main proteins of SARS-CoV-2 given with a CpG oligonucleotide adjuvant 		101
<ul style="list-style-type: none"> Bezmialem Vakif University 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
Replicating Viral Vector Vaccines			
<ul style="list-style-type: none"> University of Wisconsin-Madison FluGen Bharat Biotech 	<ul style="list-style-type: none"> Once-replicating intranasal influenza virus vaccine with the RBD of the S protein called the CoroFlu Lacks M2 gene limiting replication cycle to one Expresses hemagglutinin as an adjuvant 	<ul style="list-style-type: none"> Phase I trial (Fall 2020) 	102
<ul style="list-style-type: none"> Humane Genomics 	<ul style="list-style-type: none"> Replicating vesicular stomatitis virus (VSV) vaccine encoding SARS-CoV-2 spike (S) protein and glycoprotein of Measles virus 		103
<ul style="list-style-type: none"> Zydus Cadila 	<ul style="list-style-type: none"> Development of a recombinant measles virus (rMV) vectored vaccine 		104,105
<ul style="list-style-type: none"> Themis Institut Pasteur University of Pittsburgh Center for Vaccine Research Merck 	<ul style="list-style-type: none"> Institut Pasteur sequenced the whole viral genome of SARS-CoV-2 Measles vector vaccine to genetically express SARS-CoV-2 antigens Called V591 	<ul style="list-style-type: none"> Began animal testing (April, 2020) Not yet recruiting for Phase I clinical trials 	106–109
<ul style="list-style-type: none"> Tonix Pharma Southern Research 	<ul style="list-style-type: none"> Using viral vector of the live modified horsepox virus to express the S protein from SARS-CoV-2 Called TNX-1800 		110
<ul style="list-style-type: none"> University of Hong Kong 	<ul style="list-style-type: none"> Based on nasal spray influenza vector vaccine from Dr. Yuen Kwok-yung's lab 		3,111,112

	expressing the receptor binding domain (RBD) of the SARS-CoV-2 S protein		
<ul style="list-style-type: none"> • IAVI • Merck 	<ul style="list-style-type: none"> • Using recombinant, replication-competent VSV vector (VSVDG) to express S protein 	<ul style="list-style-type: none"> • Hopes to be in clinical trials by the end of 2020 	113,114
<ul style="list-style-type: none"> • BiOCAD • IEM 	<ul style="list-style-type: none"> • Intranasally administered viral vector vaccine developed from attenuated influenza virus vaccine 		5
<ul style="list-style-type: none"> • University of Western Ontario 	<ul style="list-style-type: none"> • VSV vaccine expressing S protein of SARS-CoV-2 		5,115
<ul style="list-style-type: none"> • KU Leuven 	<ul style="list-style-type: none"> • Yellow fever viral vector vaccine (YF17D) 	<ul style="list-style-type: none"> • Finished animal studies in hamsters • Phase I clinical trials by end of 2020 	116
<ul style="list-style-type: none"> • State Research Center of Virology and Biotechnology VECTOR • Rospotrebnadzor • Koltsovo 	<ul style="list-style-type: none"> • Approach 1: measles vector vaccine • Approach 2: intranasal recombinant influenza A viral vector vaccine • Approach 3: VSV vector vaccine 	<ul style="list-style-type: none"> • Phase I clinical trials (June 29, 2020) 	3,117
<ul style="list-style-type: none"> • Intravacc • Wageningen Bioveterinary Research • Utrecht University 	<ul style="list-style-type: none"> • Newcastle disease virus vector encoding the S protein delivered intranasally 		118
<ul style="list-style-type: none"> • The Lancaster University, UK 	<ul style="list-style-type: none"> • Avian paramyxovirus vector vaccine 		119
<ul style="list-style-type: none"> • University of California, Los Angeles 	<ul style="list-style-type: none"> • Replicating, recombinant bacterial single vector platform (LVS ΔcapB) derived from <i>F. tularensis subsp. holarctica</i> expressing multiple SARS-CoV-2 antigens 		120
<ul style="list-style-type: none"> • Fundação Oswaldo Cruz • Instituto Buntantan 	<ul style="list-style-type: none"> • Attenuated influenza vaccine expressing subunit of S protein 		3
<ul style="list-style-type: none"> • Israel Institute for Biological 	<ul style="list-style-type: none"> • VSV vaccine with glycoprotein replaced 	<ul style="list-style-type: none"> • Finished animal trials in 	121,122

<ul style="list-style-type: none"> Research Weizmann Institute of Science 	with S protein of SARS-CoV-2	hamsters	
<ul style="list-style-type: none"> Aurobindo Pharma 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker VSV vaccine 		3
<ul style="list-style-type: none"> DZIF 	<ul style="list-style-type: none"> Measles virus with antigenicity against both the S and N of SARS-CoV-2 		2
Non-Replicating Viral Vector Vaccines			
<ul style="list-style-type: none"> CanSino Biological Incorporation Beijing Institute of Biotechnology 	<ul style="list-style-type: none"> Adenovirus type 5 (Ad5-nCoV) vector encoding for the full-length S protein of SARS-CoV-2 and containing a tissue plasminogen activator signal peptide Replication deficient due to deletion of E1 and E3 	<ul style="list-style-type: none"> Published data on Phase I and Phase II clinical trials Currently in talks to launch Phase III trials in Saudi Arabia 	123–125
<ul style="list-style-type: none"> University of Oxford AstraZeneca 	<ul style="list-style-type: none"> Chimpanzee adenovirus vaccine vector (ChAdOx1) encapsulating the genetic sequence for the S protein with a tissue plasminogen activator leading sequence Delivered using lipid nanoparticle (LNP) Called AZD1222 	<ul style="list-style-type: none"> Currently undergoing Phase III clinical trials Published data on their Phase I clinical trial 	126–130
<ul style="list-style-type: none"> Janssen Pharmaceutical Companies 	<ul style="list-style-type: none"> Disabled Ad 26 vaccine with surface protein of SARS-CoV-2 called Ad26COVS1 May or may not be given with modified vaccinia ankara (MVA) as an adjuvant 	<ul style="list-style-type: none"> Currently in Phase I/II of clinical trials 	131–133
<ul style="list-style-type: none"> Gamaleya Research Institute 	<ul style="list-style-type: none"> Ad-based vaccine combining two adenoviruses: Ad5 and Ad26 Called Gam-Covid-Vac Lyo 	<ul style="list-style-type: none"> Currently in Phase III clinical trials Hopes to begin 	134–137

		production of vaccine by end of 2020	
<ul style="list-style-type: none"> • ReiThera • LEUKOCARE • Univercells 	<ul style="list-style-type: none"> • Replication defective Simian adenovirus vaccine encoding the S protein of SARS-CoV-2 from ReiThera • LEUKOCARE develops the vaccine into a highly stable liquid formulation 	<ul style="list-style-type: none"> • Currently in Phase I clinical trials 	138,139
<ul style="list-style-type: none"> • Altimune • University of Alabama at Birmingham 	<ul style="list-style-type: none"> • Intranasal vaccine given in a single-dose called AdCOVID • Adenovirus based vaccine expressing the S protein of SARS-CoV-2 	<ul style="list-style-type: none"> • Phase I clinical trial (Q3 2020) 	140,141,142
<ul style="list-style-type: none"> • Greffex 	<ul style="list-style-type: none"> • Non-replicating Ad5 vector vaccine against the S protein • GREVAX™ platform 	<ul style="list-style-type: none"> • Animal studies ongoing 	143,144
<ul style="list-style-type: none"> • Vaxart • Emergent Biosolutions 	<ul style="list-style-type: none"> • Oral, room-temperature stable vaccine based upon Vaxart's VAAST™ platform 	<ul style="list-style-type: none"> • Phase I clinical trials (second half of 2020) 	145,146
<ul style="list-style-type: none"> • Centro Nacional Biotecnología, Spain 	<ul style="list-style-type: none"> • MVA delivery of structural proteins 		3,5
<ul style="list-style-type: none"> • ImmunityBio • NantKwest 	<ul style="list-style-type: none"> • Non-replicating Ad5 vector vaccine against the S and nucleocapsid proteins 		147
<ul style="list-style-type: none"> • Shenzhen Geno-Immune Medical Institute 	<ul style="list-style-type: none"> • Approach 1: dendritic cells (DCs) modified with lentiviral vectors (LV) expressing SARS-CoV-2 minigenes with co-administration of antigen-specific cytotoxic T-lymphocytes. Named LV-SMENP-DC • Approach 2: artificial antigen-presenting cells modified with LVs expressing SARS-CoV-2 minigenes. Named pathogen-specific-aAPC 	<ul style="list-style-type: none"> • Phase I clinical trials (March 24, 2020 – Approach 1; Feb 15, 2020 – Approach 2) • Primary completion date (July 31, 2023 – Approach 1 and 2) • Study completion date (Dec 31, 2024 – Approach 1 and 2) 	148,149
<ul style="list-style-type: none"> • University of Manitoba 	<ul style="list-style-type: none"> • DC-based viral vector vaccine 		3

<ul style="list-style-type: none"> DZIF 	<ul style="list-style-type: none"> Using an attenuated viral vaccine of the modified vaccinia virus Ankara (VCA) to express the S protein of SARS-CoV-2 	<ul style="list-style-type: none"> Genetic construction of the VCA vaccine to be completed as early as April 20th 	2,3
<ul style="list-style-type: none"> GeoVax BravoVax 	<ul style="list-style-type: none"> Uses 5th generation MVA VLP as an adjuvant 	<ul style="list-style-type: none"> Narrowing vaccine candidates down to one 	150,151
<ul style="list-style-type: none"> Stabilitech Biopharma Limited 	<ul style="list-style-type: none"> Named Ora-Pro-COVID-19, an oral vaccine capsule providing both mucosal and systemic immunity Ad5 vector containing S protein DNA from SARS-CoV-2 		3,5
<ul style="list-style-type: none"> Valo Therapeutics Limited 	<ul style="list-style-type: none"> PeptiCRAd pan coronavirus vaccine Undisclosed Ad viral vector vaccine expressing SARS-CoV-2 S with HLA-matched peptides coated with PeptiCRAd technology 		3,5
<ul style="list-style-type: none"> University of Georgia University of Iowa 	<ul style="list-style-type: none"> Parainfluenza virus 5 viral vector vaccine encoding S of SARS-CoV-2 	<ul style="list-style-type: none"> Hopes for FDA approval by end of 2020 	152
<ul style="list-style-type: none"> Bharat Biotech Thomas Jefferson University 	<ul style="list-style-type: none"> COROVAX vaccine built from deactivated rabies viral vector carrying SARS-CoV-2 S1 protein 		153
<ul style="list-style-type: none"> ID Pharma 	<ul style="list-style-type: none"> Sendai virus vector-based 		3,19
<ul style="list-style-type: none"> Ankara University 	<ul style="list-style-type: none"> Ad-based 		3,5
<ul style="list-style-type: none"> Grousbeck Gene Therapy Center at Massachusetts Eye and Ear AveXis Viralgen Aldevron Catalent Penn Medicine 	<ul style="list-style-type: none"> Adeno-associated virus vector (AAVCOVID) encoding the S protein 	<ul style="list-style-type: none"> Hopes to begin Phase 1 clinical trials in the second half of 2020 	3,5,154

• Erciyes University	• Ad5-based		3,5
• National Research Centre, Egypt	• Influenza A H1N1 vector based		3,5
• National Center for Genetic Engineering and Biotechnology • GPO, Thailand	• RNA from SARS-CoV-2 spliced into inactivated influenza virus	• Preclinical trial results to be released by the end of 2020	155
• Centre for Research in Agricultural Genomics (CRAG) • Centro Nacional De Biotechnologia • Instituto De Biologia Molecular Y Celular De Plantas • Centro de Edafologia Y Biologia Aplicada Del, Segura	• Production of SARS-CoV-2 antigens in <i>Nicotiana benthamiana</i> and lettuce plants		156,157
• IDIBAPS-Hospital Clinic, Spain	• Using MVA vector encoding S protein		3,5

DNA Vaccines

• Inovio Pharmaceuticals	• Vaccine Name: INO-4800 • Optimized DNA plasmid-based vaccine given intradermally using a CELLECTRA® 2000 device encoding for the full-length S protein of SARS-CoV-2	• Currently in Phase I/II clinical trials	158–161
• Cadila Healthcare Limited	• DNA plasmid vaccine named ZYCoV-D	• Currently in Phase I/II clinical trials • Completed Phase I of the Phase I/II clinical trials	134,162,163

<ul style="list-style-type: none"> Osaka University AnGes Incorporation Takara Bio 	<ul style="list-style-type: none"> DNA plasmid encoding SARS-CoV-2 antigenic proteins given with adjuvant Also utilizing Daicel Corporation's gene-transfer technology Called AG0301-COVID19 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	164,165
<ul style="list-style-type: none"> Genexine Consortium 	<ul style="list-style-type: none"> DNA vaccine called GX-19 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	166,167
<ul style="list-style-type: none"> Karolinska Institutet Cobra Biologics Collaborations with Karolinska University Hospital, Public Health Authority, IGEA, Adlego AB, and Giessen University 	<ul style="list-style-type: none"> Project name: OPENCORONA consortium DNA vaccine given intramuscularly with electroporation that generates SARS-CoV-2 antigens 	<ul style="list-style-type: none"> Human clinical trials to begin in 2021 	168
<ul style="list-style-type: none"> Takis Applied DNA Sciences Evivax 	<ul style="list-style-type: none"> Four linear DNA vaccines produced through a PCR platform from LineaRx, a subsidiary of Applied DNA Sciences One of the vaccines encodes the full S protein while the remaining three encode epitopes within the S protein 	<ul style="list-style-type: none"> Preclinical results to be released in April Clinical testing to (fall of 2020) 	169
<ul style="list-style-type: none"> Entos Pharmaceuticals Cytiva 	<ul style="list-style-type: none"> Encapsulation of DNA plasmid encoding multiple epitopes of SARS-CoV-2 within the company's Fusogenix platform, a proteo-lipid vehicle providing direct access to the cell's cytosol Called Covigenix 		170
<ul style="list-style-type: none"> OncoSec Medical The Providence Cancer Institute 	<ul style="list-style-type: none"> Vaccine name: CORVax12 Prophylactic vaccine consists of TAVO™ (interleukin-12 or "IL-12" plasmid) combines the co-administration of TAVO™ (plasmid IL-12) with a DNA-encodable version of the SARS-CoV-2 		171

	<ul style="list-style-type: none"> spike Delivered using OncoSec's APOLLO electroporation system 		
<ul style="list-style-type: none"> Immunomic Therapeutics EpiVax PharmaJet 	<ul style="list-style-type: none"> Combining Immunomic's UNITE plasmid DNA vaccine platform, EpiVax's computational T-cell epitope prediction, and PharmaJet's Tropis® needle-free injection system 		3,172
<ul style="list-style-type: none"> University of Waterloo Mediphage Bioceuticals 	<ul style="list-style-type: none"> Targeted bacteriophage delivery of DNA-based vaccine that encodes SARS-CoV-2 VLP Delivered through a nasal spray 		173
<ul style="list-style-type: none"> Symvivo 	<ul style="list-style-type: none"> Named bacTRL-Spike Oral DNA vaccine using bifidobacterial longum bacteria that when ingested bind to epithelial cells lining the gut The bacteria replicate and release DNA plasmids encoding nanobodies and the S of SARS-CoV-2 	<ul style="list-style-type: none"> Phase I clinical trials (April 30, 2020) 	174,175
<ul style="list-style-type: none"> Bionet Asia 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> Scancell University of Nottingham 	<ul style="list-style-type: none"> DNA vaccine targeting both the S and N proteins of SARS-CoV-2 	<ul style="list-style-type: none"> Hopes to begin Phase I clinical trials in Q1, 2021 	176
<ul style="list-style-type: none"> Ege University 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3,5,177
<ul style="list-style-type: none"> National Research Centre, Egypt 	<ul style="list-style-type: none"> DNA plasmid vaccine targeting the S, S1, S2, RBD and N protein 		3,5,18
<ul style="list-style-type: none"> Chula Vaccine Research Center National Research Council 	<ul style="list-style-type: none"> DNA with electroporation 	<ul style="list-style-type: none"> Hopes to begin Phase I testing in October, 2020 	5

<ul style="list-style-type: none"> of Thailand Bionet Asia 			
<ul style="list-style-type: none"> Statens Serum Institute, Denmark 	<ul style="list-style-type: none"> Called COVAXIX, DNA plasmid 		5
<ul style="list-style-type: none"> University of Cambridge DIOSynVax 	<ul style="list-style-type: none"> Uses computational modeling to find S and coat protein epitopes that do not cause vaccine-induced enhancement 	<ul style="list-style-type: none"> Hopes to begin clinical testing in June, 2020 	178
RNA Vaccines			
<ul style="list-style-type: none"> Moderna 	<ul style="list-style-type: none"> Vaccine name: mRNA-1273 mRNA vaccine encoding for the S-2P of SARS-CoV-2 with a transmembrane anchor and intact S1-S2 cleavage site Two nucleotide substitutions within central helix of S2 keep antigen in prefusion form Encapsulation in a novel lipid nanoparticle named SM-102 	<ul style="list-style-type: none"> Published data on Phase I clinical trials Currently in Phase III of clinical trials 	179,180
<ul style="list-style-type: none"> BioNTech Pfizer Fosun Pharma 	<ul style="list-style-type: none"> Testing multiple candidates, but BNT162b1 has progressed furthest and most public information is about this candidate Encodes for the RBD of SARS-CoV-2 and contains 1-methyl-pseudouridine mutations for increased translation and decreased immunogenicity Constructed on T4 fibrin-derived “foldon” trimerization base Encapsulated within a lipid nanoparticle 	<ul style="list-style-type: none"> Publishing data on Phase I clinical trials Currently in Phase II/III of clinical trials 	181–183
<ul style="list-style-type: none"> Vaccine Test 	<ul style="list-style-type: none"> No public information other than a listing in the Milken Institute SARS-CoV-2 vaccine tracker 		5

<ul style="list-style-type: none"> CureVac 	<ul style="list-style-type: none"> Protamine-complexed mRNA-based vaccine expressing S protein of SARS-CoV-2 and formulated within LNPs Called CVnCoV 	<ul style="list-style-type: none"> Currently in Phase I clinical trials 	184,185
<ul style="list-style-type: none"> Arcturus Therapeutics Duke-NUS program 	<ul style="list-style-type: none"> Self-replicating mRNA vaccine using LUNAR (Lipid-enabled and Unlocked Nucleomonomer Agent modified RNA) technology Called ARCT-021 	<ul style="list-style-type: none"> Currently in Phase I/II clinical trials 	186–188
<ul style="list-style-type: none"> eTheRNA Immunotherapies EpiVax Nexelis REPROCELL Center for Evaluation of Vaccination at the University of Antwerp 	<ul style="list-style-type: none"> Vaccine with TriMix platform containing mRNA encoding caTLR4, CD40L, and CD70 on a single mRNA construct Intranasal delivery platform 	<ul style="list-style-type: none"> Hoping to begin clinical testing and patient enrollment in early 2021 	189,190
<ul style="list-style-type: none"> Sanofi Pasteur Translate Bio 	<ul style="list-style-type: none"> Liposome-based mRNA vaccine built out from Translate Bio's mRNA therapeutic platform 	<ul style="list-style-type: none"> Hopes to begin clinical trials (Q4 of 2020) 	191–194
<ul style="list-style-type: none"> Guanhao Biotech Zy Therapeutics 	<ul style="list-style-type: none"> Series of mRNA vaccines as a freeze-drying powder injection Delivered using Zy Therapeutic's non-toxic nucleic acid delivery polymer ZY-030 		195,196
<ul style="list-style-type: none"> Tongji University Stermirna Therapeutics Chinese CDC 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Currently studying in mice 	3,197
<ul style="list-style-type: none"> Ziphius Therapeutics Ghent University 	<ul style="list-style-type: none"> ZIP-1642 Combination of mRNA molecules encoding for multiple SARS-CoV-2 proteins 	<ul style="list-style-type: none"> Hopes to have a product for clinical testing by August/September 	198
<ul style="list-style-type: none"> RNACure Biopharma Fudan University 	<ul style="list-style-type: none"> Approach 1: mRNA expressing the RBD of the S protein 		199

<ul style="list-style-type: none"> Shanghai JiaoTong University 	<ul style="list-style-type: none"> Approach 2: mRNA cocktails that instructs the hosts to produce VLPs Lipid nanoparticle delivery 		
<ul style="list-style-type: none"> Imperial College London 	<ul style="list-style-type: none"> Self-amplifying RNA vaccine to express S protein of SARS-CoV-2 	<ul style="list-style-type: none"> Currently in Phase I clinical trials 	200–203
<ul style="list-style-type: none"> Centro Nacional Biotecnología, Spain 	<ul style="list-style-type: none"> Self-replicating RNAs for defective SARS-CoV-2 		3
<ul style="list-style-type: none"> University of Tokyo Daiichi-Sankyo 	<ul style="list-style-type: none"> mRNA vaccine delivered via lipid nanoparticle 	<ul style="list-style-type: none"> Hopes to begin animal studies (March, 2021) 	204,205
<ul style="list-style-type: none"> BiOCAD 	<ul style="list-style-type: none"> mRNA vaccine based off of previous mRNA oncogenic vaccine delivered via liposomal 	<ul style="list-style-type: none"> Animal studies started end of April, 2020 	206,207
<ul style="list-style-type: none"> GeneOne Life Science Houston Methodist 	<ul style="list-style-type: none"> No public information other than a listing in the Milken Institute SARS-CoV-2 vaccine tracker 		5,208
<ul style="list-style-type: none"> RNAimmune Incorporation 	<ul style="list-style-type: none"> Developing several mRNA vaccines delivered using proprietary polypeptide-lipid nanoparticle 		209
<ul style="list-style-type: none"> State Research Center of Virology and Biotechnology VECTOR Rospotrebnadzor Koltsovo 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 	<ul style="list-style-type: none"> Phase I clinical trials (June 29, 2020) 	117
<ul style="list-style-type: none"> Greenlight Biosciences 	<ul style="list-style-type: none"> mRNA vaccine 	<ul style="list-style-type: none"> Currently testing immunogenicity of coronavirus vaccines preclinically 	210
<ul style="list-style-type: none"> Cansino Biologics Precision Nanosystems 	<ul style="list-style-type: none"> Utilizing Precision Nanosystem's proprietary lipid nanoparticle delivery system with its NanoAssemblr® manufacturing technology 		211
<ul style="list-style-type: none"> Rochester Clinical Research 	<ul style="list-style-type: none"> No public information other than a listing 		212

	in the Regulatory Affairs Professional Society SARS-CoV-2 vaccine tracker		
<ul style="list-style-type: none"> IDIBAPS-Hospital Clinic, Spain 	<ul style="list-style-type: none"> mRNA vaccine co-formulated with nanoparticles 		213
<ul style="list-style-type: none"> Chula Vaccine Research Center University of Pennsylvania 	<ul style="list-style-type: none"> Hopes to be a cheaper, lipid nanoparticle, mRNA vaccine 	<ul style="list-style-type: none"> Clinical trials to begin in October Vaccine to be ready by 2021 	214
<ul style="list-style-type: none"> Selcuk University 	<ul style="list-style-type: none"> No public information other than a listing in the World Health Organization SARS-CoV-2 vaccine tracker 		3
<ul style="list-style-type: none"> Genova 	<ul style="list-style-type: none"> Named HGC019 Self-amplifying mRNA vaccine against S protein and delivered using lipid inorganic nanoparticle 	<ul style="list-style-type: none"> Completed animal studies Hopes to begin clinical tests by end of 2020 	215
<ul style="list-style-type: none"> Elixirgen Therapeutics 	<ul style="list-style-type: none"> Self-replicating RNA vaccine encoding the RBD of SARS-CoV-2 Called EXG-5003 	<ul style="list-style-type: none"> Concluded pre-Investigational New Drug meeting with FDA on May 18, 2020 	216
<ul style="list-style-type: none"> Chimeron Bio George Mason University's National Center for Biodefense and Infectious Disease 	<ul style="list-style-type: none"> Vaccine utilizes the company's ChaESAR™ self-amplifying and self-assembling RNA delivery technology to deliver RNA encoding SARS-CoV-2 antigens 		217
<ul style="list-style-type: none"> Max Planck Institute of Colloids and Interfaces 	<ul style="list-style-type: none"> mRNA vaccine delivered using a Langerhans Cell Targeted Delivery System directly into the skin 		5,218
<ul style="list-style-type: none"> People's Liberation Army Academy of Military Sciences 	<ul style="list-style-type: none"> mRNA vaccine called ARCoV 	<ul style="list-style-type: none"> Currently in Phase I of clinical testing 	219,220

• Walvax Biotech			
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